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Phonetic radicals, not phonological coding systems, support orthographic learning via self-teaching in Chinese

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ABSTRACT

According to the self-teaching hypothesis (Share, 1995), phonological decoding is fundamental to acquiring orthographic representations of novel written words. However, phonological decoding is not straightforward in non-alphabetic scripts such as Chinese, where words are presented as characters. Here, we present the first study investigating the role of phonological decoding in orthographic learning in Chinese. We examined two possible types of phonological decoding: the use of phonetic radicals, an internal phonological aid, and the use of Zhuyin, an external phonological coding system. Seventy-three Grade 2 children were taught the pronunciations and meanings of twelve novel compound characters over four days. They were then exposed to the written characters in short stories, and were assessed on their reading accuracy and on their subsequent orthographic learning via orthographic choice and spelling tasks. The novel characters were assigned three different types of pronunciation in relation to its phonetic radical – (1) a pronunciation that is identical to the phonetic radical in isolation; (2) a common alternative pronunciation associated with the phonetic radical when it appears in other characters; and (3) a pronunciation that is unrelated to the phonetic radical. The presence of Zhuyin was also manipulated. The children read the novel characters more accurately when phonological cues from the phonetic radicals were available and in the presence of Zhuyin. However, only the phonetic radicals facilitated orthographic learning. The findings provide the first empirical evidence of orthographic learning via self-teaching in Chinese, and reveal how phonological decoding functions to support learning in non-alphabetic writing systems.

1. Introduction

In order to read fluently, one needs to be able to recognise written words rapidly and automatically (Perfetti, 1992). The *self-teaching hypothesis* (Share, 1995) suggests that orthographic learning, the transition from laborious alphabetic decoding to fluent whole word recognition (Castles & Nation, 2006; Nation & Castles, 2017), depends on converting print to speech sounds, or phonological decoding. This hypothesis has been tested and supported in many alphabetic languages (e.g., English: Cunningham, 2006; Dutch: de Jong, Bitter, van Setten, & Marinus, 2009; Hebrew: Share, 2004). Given the growing interest in the universals of learning to read (Perfetti, Cao, & Booth, 2013; Share, 2015), an important question arises as to whether learning to read in non-alphabetic languages is dependent on a similar process. The present study tests the self-teaching hypothesis in a non-alphabetic language, Chinese. Specifically, for the first time, we investigate the role of phonological decoding in orthographic learning by self-teaching in Chinese. We examine both the use of the phonetic radical, the internal phonological aid, and Zhuyin, the external phonological coding system.

According to the self-teaching hypothesis (Share, 1995), phonological decoding draws the reader's attention to a novel word's orthographic details, and thus functions as a self-teaching mechanism children use to learn to read new words. This hypothesis makes two important claims about the acquisition of word-specific orthographic representations. First, orthographic knowledge of a word can be acquired without explicit teaching. Second, and more critically, orthographic learning is dependent on phonological decoding as a necessary condition. To test this hypothesis, Share (1999) asked second grade Hebrew-speaking children to read aloud pseudowords (e.g., *yait*) in the context of stories. Three days later, the children spelled the target pseudowords more accurately, named them more rapidly and correctly identified them more often than the alternative homophonic spellings (e.g., *yate*). These results suggested that word-specific orthographic learning had taken place. In a separate experiment, another group of children performed a lexical decision task with concurrent articulation (repeatedly saying "dubba" aloud), where phonological decoding was reduced. The results showed that orthographic learning was greater in the read aloud condition than in the concurrent articulation condition,

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suggesting that phonological decoding contributes directly to orthographic learning. de Jong et al. (2009) and Kyte and Johnson (2006) replicated these results in Dutch and English respectively. The importance of phonological decoding is also supported by studies showing a positive correlation between correct decoding and successful orthographic learning (Bowey & Miller, 2007; Cunningham, 2006; Cunningham, Perry, Stanovich, & Share, 2002; Kyte & Johnson, 2006).

The reliance on phonological decoding in orthographic learning can also be revealed by a word regularity effect. In alphabetic languages, regular words (e.g., *cheap*) are processed more accurately than irregular words (e.g., *breath*), as has been shown in children's word naming (e.g., Laxon, Masterson, & Coltheart, 1991) and lexical decision tasks (e.g., Schmalz, Marinus, & Castles, 2013). This effect has often been used to index the degree of reliance on phonological decoding. If phonological decoding is indeed the foundation of orthographic learning, the regularity effect should also be found in word learning. Wang, Castles, and Nickels (2012) tested this hypothesis using a modified version of the self-teaching paradigm. They trained Grade 3 children to read regular pseudowords (e.g., *ferb,* pronounced as "ferb") and irregular pseudowords (e.g., *cleap,* pronounced as "clape"). Ten days later, orthographic learning was assessed with a spelling and an orthographic decision task. It was indeed found that regular items gained stronger orthographic representations than irregular ones, suggesting that orthographic learning is less effective when only partial decoding is possible, as in the irregular words.

Yet the precise nature of phonological decoding remains unclear. Share (1995) adopted a very broad definition of phonological decoding to refer it to the process of deriving speech information from print "through whatever means" (p. 152). In other words, phonological decoding is not restricted to grapheme-phoneme conversion but could, for instance, also involve the use of larger units like bodies and rimes, or even phonetic radicals and characters in Chinese. However, the latter possibilities have not been tested.

In Chinese, there are no grapheme-phoneme correspondences in the writing system. Instead, a character, the basic reading unit in Chinese (see discussion in Li & McBride, 2014), represents a morpheme and maps onto the sound of an entire syllable rather than smaller phonological units such as phonemes. Therefore, the print-to-sound conversion is entirely syllable based. Notably, only a subcomponent of a character contains phonological information. An estimated 80–90% of modern Chinese (Kang, 1993) and 72% of elementary textbooks (Shu, Chen, Anderson, Wu, & Xuan, 2003) consist of compound characters (or "compounds") with a semantic and a phonetic radical. For example, 油 |you2| ("oil") is composed of a semantic radical 氵 meaning "liquid" on the left and a phonetic radical 由 |you2| on the right. Given that only the phonetic radical of a whole character provides phonological information, phonological decoding is always "partial" in Chinese. Previous studies in reading development of Chinese suggest that Chinese children are sensitive to the radicals as subcomponents of compounds. For example, they can copy pseudocharacters better when they are formed by discernible radicals than arbitrary strokes (Anderson et al., 2013), and when the radicals are in familiar positions than in illegal positions (Anderson et al., 2013; Tong & McBride, 2014). They are also aware of the phonetic radical's function and use it in naming compounds (Ho & Bryant, 1997; Shu, Anderson, & Wu, 2000) and in learning compounds' pronunciations (Anderson, Li, Ku, Shu, & Wu, 2003; Chen, Anderson, Li, & Shu, 2014; He, Wang, & Anderson, 2005; Yin & McBride, 2015). Yet, whether the phonetic radical is used as a way to "phonologically decode" an unfamiliar compound to achieve orthographic learning is not clear. Hence, the first aim of this study was to investigate whether the phonetic radical is utilised as a means of phonological decoding during orthographic learning in Chinese.

In addition, it has been found that children not only use the phonetic radicals directly, but also use analogy to read unfamiliar characters (Chen et al., 2014; He et al., 2005; Ho, Wong, & Chan, 1999). That is, children can either infer the pronunciation of an unfamiliar compound by its phonetic radical, or, they can infer the pronunciation by making an analogy to another compound that contains the same phonetic radical but has a different pronunciation to the phonetic radical. Chen et al. (2014) investigated whether young children use known characters to read novel ones via direct mapping from phonetic radicals or via analogy. In their study, the children first learned to read a clue character (e.g., 胥|xu4|), and were then asked to name an unknown target compound character (e.g., 揟|xu4|) where the clue character functioned as the phonetic radical. The target therefore could be read via the clue character acting as its phonetic radical. In another condition, the clue and the target were both compounds sharing the same phonetic radical (e.g., 濬|jin4| and繙|jin4|). Hence, the target could be read by making an analogy to the clue character. The children's naming accuracy of the target compounds did not differ significantly between the two conditions, indicating that they used both phonetic radicals and whole characters (analogy) to read unfamiliar compounds. It was also found that when both ways were available, younger children used more direct mapping while older children used more analogy to read unknown compounds. These two approaches to phonological decoding via the phonetic radical are called the "phonetic strategy" and the "analogy strategy" (Chen et al., 2014; He et al., 2005; Ho et al., 1999). Although these previous studies suggested that children do use information from phonetic radicals when reading unfamiliar compounds, whether this strategy facilitates orthographic learning remains untested.

The second proposed type of phonological decoding we aim to explore is the role of Zhuyin or Pinyin. Zhuyin and Pinyin are external phonological coding systems used in Taiwan and Mainland China respectively. These systems are taught at the beginning of elementary school, and are normally mastered by the children by the end of the first semester (Cheung & Ng, 2003). They are presented to children alongside characters in textbooks. Since these external aids are highly consistent in orthography-to-phonology conversions, children can use them to reliably sound out any unfamiliar character. It could be argued that reading with Zhuyin/Pinyin, compared to phonetic radicals, permits more successful and reliable decoding, which allows for better conditions to build up entries in the orthographic lexicon (Lin et al., 2010; Share, 1995).

Importantly, investigating whether Zhuyin facilitates orthographic learning provides a unique opportunity to better understand how phonological decoding contributes to orthographic learning. Although phonological decoding and orthographic learning have now been investigated for more than two decades, exactly how phonological decoding promotes successful orthographic learning is far from clear. Previous research has demonstrated that successful phonological decoding does not necessarily lead to orthographic learning at an item level (Nation, Angell, & Castles, 2007; Wang, Nickels, Nation, & Castles, 2013). A recent study has also found that using text-to-speech software, although providing the correct phonology by reading aloud each word, had no impact on orthographic learning (as revealed by spelling and word naming) or even a negative one (as revealed by orthographic choice) in poor readers of Dutch (Staels & Van den Broeck, 2015). These findings seem to support Share's (2004, 2008) claim that while phonological decoding is necessary, correct phonological decoding does not guarantee successful orthographic learning. More importantly, the function of phonological decoding is not only to provide the phonological forms that can be mapped on to orthographic representations, but also to draw the reader's attention to the orthographic details (see also Ehri, 2014). However, this latter proposal has never been directly tested. If the benefit of phonological decoding is to activate the correct phonology, then Zhuyin should facilitate learning. On the other hand, decoding via Zhuyin potentially draws readers' attention away from the characters and could hence interfere with the establishment of specified orthographic representations. Thus, if the benefit of phonological decoding is more about attending to the orthographic details, then Zhuyin may hinder orthographic learning.